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DOT HS-803-397

TESTING AN IMPROVED FMVSS NO. 104 WINDSHIELD WASHER PROCEDURE AND SPRAY

Roy W. Hull
Dr. Leon M. Adams
Clark E. Schuetze

Southwest Reasearch Institute
8500 Culebra Rd.
San Antonio, Texas 78284

Contract No. DOT HS-6-01407
Contract Amt. $28,130

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FEBRUARY 1977
FINAL REPORT

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Springfield, Virginia 22161

Prepared For
U.S. DEPARTMENT OF TRANSPORTATION
National Highway Traffic Safety Administration
Washington, D.C. 20590

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TL
242
.49

TECHNICAL REPORT STANDARD TITLE PAGE

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
DOT HS-803 397		

4. Title and Subtitle
TESTING OF AN IMPROVED FMVSS NO. 104 WINDSHIELD WASHER PROCEDURE AND SPRAY

5. Report Date
February 1977

6. Performing Organization Code

7. Author(s)
Roy W. Hull, Leon M. Adams, Clarke E. Schuetze

8. Performing Organization Report No.
AR 1150

9. Performing Organization Name and Address
Southwest Research Institute
8500 Culebra Road
San Antonio, Texas 78284

10. Work Unit No.

11. Contract or Grant No.
DOT-HS-6-01407

12. Sponsoring Agency Name and Address
National Highway Traffic Safety Administration
Department of Transportation
Washington, D.C. 20590

13. Type of Report and Period Covered
FINAL REPORT
1 July 1976 to
28 February 1977

14. Sponsoring Agency Code

Dept. of Transportation
DEC 19 1978
Library

15. Supplementary Notes
Southwest Research Institute Project No. 11-4603

16. Abstract

An improved windshield washer test mixture was developed and the test procedure was updated to evaluate windshield washer performance using the new test mixture.

The improved test mixture contains four components which are (1) a clay in fine particle size which forms a colloidal suspension in water, (2) a poly(vinyl alcohol) resin which adds tenaceous properties, (3) titanium dioxide which adds a highly visible whiteness and (4) deionized water.

The selected test mixture formulation consists of low cost readily available components that are easy to prepare. The mixture is easily applied with a hand sprayer and gives a uniform coating due to the good suspension properties of the solid components. The film is sufficiently difficult to remove that poor washer systems can be identified.

The test procedure is a modification of the FMVSS 104, TP-104-04 procedure for testing windshield wiper and washer systems. The most significant change is the addition of a photometric technique to determine the amount of test dirt on the glazed surface.

17. Key Words	18. Distribution Statement
compliance testing, windshield washers, windshield dirt film, windshield washer testing, windshield light transmission, photometric measurements	Document is available to the public through the National Technical Information Service, Springfield, Virginia 22161

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
UNCLASSIFIED	UNCLASSIFIED	61	

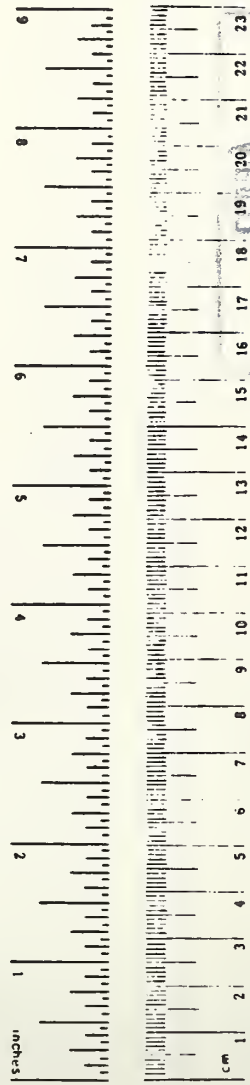
Form DOT F 1700.7 (8-69)

METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
	LENGTH			
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
	AREA			
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
	MASS (weight)			
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
	VOLUME			
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
	TEMPERATURE (exact)			
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.



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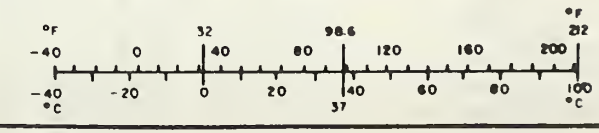
Symbol	When You Know	Multiply by	To Find	Symbol
	LENGTH			
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
	AREA			
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
	MASS (weight)			
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
	VOLUME			
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
	TEMPERATURE (exact)			
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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I. INTRODUCTION

The objective of this program was to develop and test an improved windshield washer spray mixture using an updated evaluation procedure. The data obtained is intended for use in revising the windshield washer compliance test procedures in future rulemaking involving FMVSS No. 104, "Windshield Wiping and Washing Systems".

The original SAE Recommended Practice J942, "Passenger Car Windshield Washer Systems", November 1975, provided that the washer test mixture be composed of water and Arizona Dust. This Recommended Practice was incorporated in the initial FMVSS No. 104 and its subsequent April 1968 amendment on wiping and washing systems. A later SAE revision, J942b, July 1972, modified this test mixture to include salt (sodium chloride). A 1970 report by the Virginia Highway Research Council, "Composition and Removal of Automotive Windshield Films", provided information on an actual sample of road film which included materials or substances different from that used by the SAE in its washer test.

Subsequent studies were funded by NHTSA which evaluated different spray mixtures. These studies concluded that the Arizona Dust film was not representative of actual road film, but the Virginia Dirt film analysis seemed a reasonable facsimile of actual dirt films.

The program reported herein was funded by NHTSA for the purpose of improving the dirt film mixture to be used in compliance test procedures involving FMVSS NO. 104 and to develop a practical and repeatable vehicle compliance test procedure to evaluate windshield washer performance.

II. TECHNICAL PROGRAM

A. WINDSHIELD DIRT FILM

1. Evaluation of Previously Developed Test Mixtures

Prior studies of windshield dirt films for use in FMVSS 104 compliance testing resulted in the development of a recommended dirt film identified by the contractor as "4B".(1) The formulation of this 4B dirt film is the following:

	% by wt.
Stewart Clay, 0-100 μM	78.5
Arizona dust (fine)	16.5
Macerated fresh cockroaches	1.5
Used motor oil, 10W-40	3.0
Finely powdered asphalt, 0-100 μM	0.25
Finely powdered tire rubber, 0-100 μM	0.25

Recommendations for further study made by the contractor who developed the 4B dirt film included the following:

- °Determine effects of exclusion of constituents in dirt film to produce a simpler formulation.
- °Determine the feasibility of substituting CMC or another chemical for insect fluids.

At the beginning of SwRI's evaluation, a 4B dirt film was made which approximately duplicated the formulation listed above. The formulation was approximate because a source for one of the components, Stewart clay, could not be found. In place of Stewart clay, an Amoco 46D clay was used. The resulting formulation, when used to test a vehicle washer/wiper system, seemed much too easy to remove. The first trial pointed out the need for a formulation for which all components can be explicitly defined and for which sources are readily available. A second observation made was that, to provide some degree of difficulty to the test, a more tenacious mixture than the 4B would be required. The 4B mixture was also found to have a short suspension time. Frequent shaking, even while applying, was necessary to prevent solids in the mixture from settling.

The Laboratory Procedure TP-104-04 for "Windshield Wiping and Washing Systems - Passenger Cars, Multipurpose Passenger Vehicles, Trucks and Buses" specifies a test mixture composed of one part test dust and two parts water by volume. The SAE Recommended Practice J942 calls for a similar test mixture except the inclusion of a 5% by volume of saturated salt water is specified. These test mixtures are not considered to be difficult to remove and therefore would not be selective in identifying good and poor washer systems.

2. Development of a New Test Mixture

During this study, 28 different dirt film formulations were made

TABLE 1. EXPERIMENTAL DIRT FILMS EVALUATED

Designation	Formulation
3A	20g Amaco 46D clay (American Art Clay Co.) 20 ml 1% aqueous solution Gelvatol 20-60 (Monsanto) 800 ml deionized water
3B	20g Amaco 46D clay 20 ml 1% aqueous solution Elvanol 71-30 (DuPont) 800 ml deionized water
3C	20g Amaco 46D clay 20 ml 1% aqueous solution Elvanol 90-50 (DuPont) 800 ml deionized water
3D	20g Mineral Colloid BP (Georgia-Kaolin Co.) 20 ml 1% aqueous solution Gelvatol 1/30 800 ml deionized water
4B	15.7g Amaco 46D clay 3.3g Arizona dust (fine) 0.3g fresh cockroaches 0.6g used 10W-40 oil 0.05g oxidized asphalt, 100μ 0.05g tire rubber, 100μ 800 ml deionized water
4D	20g Mineral Colloid BP 20 ml 1% Ethyl Hydroxyethyl Cellulose 55K (Hercules) 800 ml deionized water
4E	20g Mineral Colloid BP 20 ml 1% Gelvatol 20-60 aqueous solution 800 ml deionized water
5A	20g Mineral Colloid BP 20 ml 1% aqueous solution, Gelvatol 20-60 1g Tullanox hydrophobic fumed silica (Tulco, Inc.) wet with 15 ml isopropanol 800 ml deionized water
6A	6g Bentone LT (bentonite gel) 10g Pyrax ABB (clay) 800 ml deionized water
6B	20g Mineral Colloid BP 20 ml 1% Gelvatol 20-60 aqueous solution 1g radiant fluorescent pigment - orange-red, Type R-103-G114 (Hercules) 800 ml deionized water
7A	20g Mineral Colloid BP 20 ml 1% Gelvatol 20-60 aqueous solution 1g Kroma Red RO-8097 (Williams Colors & Pigments) 800 ml deionized water
7B	20g Mineral Colloid BP 20 ml 1% Gelvatol 20-60 aqueous solution 1g carbon black, Sterling RX-76 V-7688 (Cabot Corp.) 800 ml deionized water

TABLE 1. EXPERIMENTAL DIRT FILMS EVALUATED (Cont'd.)

Designation	Formulation
7C	20g Mineral Colloid BP 20 ml 1% Gelvatol 20-60 aqueous solution 1g titanium dioxide, Ti-Pure R-900 (DuPont) 800 ml deionized water
8A	40g Mineral Colloid BP 20 ml 2% aqueous Gelvatol 20-60 solution 800 ml deionized water
8B	20g Micro Cel E (Johns-Manville) 10 ml 2% aqueous Gelvatol 20-60 solution 800 ml deionized water
8C	20g Mineral Colloid BP 10 ml 2% aqueous Gelvatol 20-60 solution 1g fluorescent dye Tinopal CBS (Ciba-Geigy) 800 ml deionized water
8D	20g Mineral Colloid BP 10 ml 2% aqueous Gelvatol 20-60 solution 1g fluorescent dye Calcofluor (Cyanamid) 800 ml deionized water
8E	20g Mineral Colloid BP 10 ml 2% aqueous Gelvatol 20-60 solution 1g white pigment, Calcofluor (Cyanamid) 800 ml deionized water
8F	20g Mineral Colloid BP 10 ml 2% aqueous Gelvatol 20-60 solution 3g titanium dioxide Ti-Pure R-900 (DuPont) 800 ml deionized water
9C	30g Mineral Colloid BP 15 ml 2% Gelvatol 20-60 aqueous solution 800 ml deionized water
9D	25g Mineral Colloid BP 15 ml 2% Gelvatol 20-60 aqueous solution 2.5g Ti-Pure R-900 2.5g Silane EF (Calcium Silicate-PPG) 800 ml deionized water
9E	20g Mineral Colloid BP 10 ml 2% Gelvatol 20-60 aqueous solution 2.5g Ti-Pure R-900 2.5g Silane EF (Calcium Silicate-PPG) 800 ml deionized water
9F	20g Mineral Colloid BP 1g fluorescent dye Tinopal CBS 800 ml deionized water

TABLE 1. EXPERIMENTAL DIRT FILMS EVALUATED (Cont'd.)

Designation	Formulation
10A	20g Mineral Colloid BP 10 ml 2% Gelvatol 20-60 aqueous solution 1g fluorescent dye Tinopal CBS 2g titanium dioxide Ti-Pure R-900 800 ml deionized water
10B	20g Mineral Colloid BP 3g titanium dioxide Ti-Pure R-900 800 ml deionized water
11B	Same as 8F except a new supply of Mineral Colloid BP was used.
11C	Same as 8F except 0.4g fungicide Dowicide G, was added.
12A	20g Volclay No. 325 (American Colloid Co.) 10 ml 2% Gelvatol 20-60 aqueous solution 3g titanium dioxide, Ti-Pure R-900 800 ml deionized water
12B	20g Volclay HPM-20 10 ml 2% Gelvatol 20-60 aqueous solution 3g titanium dioxide, Ti-Pure R-900 800 ml deionized water
12C	20g Veegum T (R.T. Vanderbilt Co.) 10 ml 2% Gelvatol 20-60 aqueous solution 3g titanium dioxide, Ti-Pure R-900 800 ml deionized water
12D	20g Veegum regular 10 ml 2% Gelvatol 20-60 aqueous solution 3g titanium dioxide, Ti-Pure R-900 800 ml deionized water

TABLE 2. EVALUATION OF DIFFERENT TEST FLUIDS ON VEHICLES

Test Fluid	Vehicles	Comments
3A	1976 Ford Elite 1977 Buick LeSabre	Visibility of remaining film not adequate
3B	1976 Ford Elite	Film too easily removed
3C	1976 Ford Elite	Film too easily removed
3D	1976 Ford Elite	Film too easily removed
4B	1976 Ford Elite 1976 Dodge Van	Film too easily removed
4D	1976 Ford Elite	During washer/wiper test the dirt film formed jelly-like deposits on wiper blade which carried back and forth. Clean area was difficult to define.
4E	1976 Ford Elite 1973 Chevrolet Impala 1976 Chevrolet Chevette	Remaining film not easily seen after washer/wiper test
5A	1976 Ford Elite 1969 Buick LeSabre 1976 Dodge Van	Film is too difficult to remove with washer/wiper
6A	1976 Ford Elite	Film is too difficult to remove with washer/wiper
6B	Not tested on vehicle	Poor fluorescence on test panel
7A	Not tested on vehicle	Poor visibility on test panel
7B	Not tested on vehicle	Poor visibility on test panel
7C	1976 Plymouth Gran Fury 1976 Dodge Aspen	Dirt film too difficult to remove with washer/wiper
8A	1966 AMC Ambassador	Dirt film too difficult to remove This film is similar to 4E except 8A has twice as much Mineral Colloid.
8B	Not tested on vehicle	Solids settle in 1 hour. Redisperse easily. Easily removed from glass test panel.
8C	1966 AMC Ambassador 1976 Oldsmobile Cutlass	Film too difficult to remove. Fluorescent pigment shows up well when viewed under ultraviolet light.

TABLE 2. EVALUATION OF DIFFERENT TEST FLUIDS ON VEHICLES (Cont'd.)

Test Fluid	Vehicles	Comments
8D	Not tested on vehicle	Poor fluorescence. Difficult to disperse.
8E	Not tested on vehicle	Poor fluorescence
8F	1966 AMC Ambassador 1976 Dodge Aspen 1976 Oldsmobile Cutlass 1976 Plymouth Gran Fury 1972 Chevrolet Pickup Truck 1976 AMC Pacer 1976 Ford Van 1976 Volvo 244DL 1976 Dodge Van	This dirt film is same as 4E except 2% Gelvatol 20-60 is used and titanium dioxide was added to make remaining film more visible. This film was completely removed by good washer/wiper systems but was not completely removed by washer systems that deliver small amounts of water nor by systems that poorly distribute the water. Remaining dirt film was easily seen.
9C	Not tested on vehicle	
9D	1976 AMC Ambassador 1976 Dodge Aspen	Difficult to remove with washer/wiper system.
9E	1976 Oldsmobile Cutlass 1972 Chevrolet Pickup Truck	Difficult to remove with washer/wiper system.
9F	1976 Oldsmobile Cutlass 1977 Buick LeSabre 1976 AMC Pacer	Fluorescent pigment shows up well under ultraviolet light.
10A	1976 Oldsmobile Cutlass	Film difficult to remove in areas remote from water spray contact point.
10B	1972 Chevrolet Pickup 1976 Dodge Aspen 1976 Plymouth Gran Fury	Too easily removed with the washer/wiper systems
11B (8F)	1976 Dodge Aspen 1977 Buick LeSabre	This film has same formulation as 8F. A new supply of Mineral Colloid was obtained and tested for comparison with the original batch. No differences in test results were noted.
11C (8F + fungicide)	1976 Dodge Aspen 1977 Buick LeSabre	This film has same formulation as 8F except a fungicide was added. No differences in test results were noted.
12A	1976 Dodge Aspen	Dirt film does not apply evenly.

TABLE 2. EVALUATION OF DIFFERENT TEST FLUIDS ON VEHICLES (Cont'd.)

Test Fluid	Vehicles	Comments
12B	Not tested on vehicle	Film uneven on test panel.
12C	1976 Dodge Aspen	This film is more opaque than 8F. Ease of removal is equal to 8F.
12D	1976 Dodge Aspen	This film is more opaque than 8F. Film is easier to remove than 8F.

and evaluated. Efforts were made to keep the number of components at a minimum and preparation as simple as possible while maintaining performance. Components were chosen with regard for stability, harmlessness and availability. Table 1 lists the different formulations evaluated.

The characteristics sought in preparing the different experimental dirt films were:

- °Proper degree of difficulty in removal. A dirt film that could be removed in about 10 cycles of a good washer/wiper system was thought to be suitable for screening out bad systems.
- °Good visibility of the remaining dirt film after testing. Two approaches to improving the dirt film visibility were used. One was to add pigments to the mixture to cause the remaining film to be easily seen against a selected background. The other approach was to include a fluorescent dye in the mixture and view the remaining dirt film under an ultraviolet light. Each approach yielded a dirt film that was considered satisfactory.
- °Prolonged suspension of the particles in the dirt film. Different clays and different suspending agents were tried. Particle size was a factor in the control of particle settling time.
- °Uniformity of coating of glazed area. Good particle suspension characteristics influenced the uniformity of coating.

Table 2 lists the different vehicles on which the experimental formulations were tested. These tests are discussed in the following Section II-B.

During the evaluation of the experimental dirt films on vehicles, the choices were narrowed down to two which were: 8F (nonfluorescent) and 9F (fluorescent). There seemed to be no advantage in using the fluorescent dirt film over the 8F film. The use of the fluorescent film required a darkened room and an ultraviolet lamp. These are not serious penalties; however, since the nonfluorescent 8F film is easily viewed in daylight, it is considered slightly more convenient to use and thus is considered the preferred dirt film.

The 8F dirt film formulation selected as being the best of those evaluated contains the following constituents in the proportions indicated:

20g Mineral Colloid BP (clay in fine particle form)
10 ml 2% aqueous Gelvatol 20-60 solution poly(vinyl alcohol)
800 ml deionized water
3g Ti-Pure R-900 (titanium dioxide).

Sources for the components of this 8F formulation are:

Mineral Colloid BP - Georgia Kaolin Co. (distributed by Thompson-Hayward Chemical Co.)

Gelvatol 20-60 solution poly(vinyl alcohol) - Monsanto Chemical Co.

Ti-Pure R-900 (titanium dioxide) - DuPont.

These sources are well established companies and can be relied upon to supply these materials in the foreseeable future. Appendix A contains additional information on these materials and sources.

3. Descriptions of Components Used in 8F Test Mixture

The final solution selected conforms well with the initial objectives of minimizing components and keeping the preparation as simple as possible while obtaining satisfactory performance. A brief description of the components is as follows:

Mineral Colloid BP is manufactured by the Georgia Kaolin Company from the clay mineral montmorillonite. The material sells for about $0.60 per pound. A technical data sheet and list of distributors is given in Appendix A. The material forms a suspension of particles in water in the range of about one micron and less and this does not settle enough to change the concentration during use. The suspensions are easily redispersed after settling for months. The material provides viscosity, film formation and some adhesion to the glass surface. The clay is not subject to attack by microorganisms. No hazard should be involved in its use in this application.

Ti-Pure R-900, a rutile titanium dioxide, is manufactured by DuPont. This is a widely used white paint pigment of small particle size. It gives density and a highly visible whiteness to the film. It is stable, inert, and not affected by microorganisms. It should be harmless as used. It sells for about $0.48 per pound. Properties of Ti-Pure R-900 are given in Appendix A.

Gelvatol 20-60 poly(vinyl alcohol), manufactured by Monsanto Company is a water-soluble, partially hydrolyzed (88.7-85.5%) poly(vinyl alcohol) resin of a molecular weight of about 96,000. It is widely used as an adhesive and film forming binder. The aqueous solution is relatively stable. The material will support mold growth on long standing. It is harmless as used. Price of the material is about $1.00 a pound. Data sheets are in Appendix A.

Demineralized or distilled water is recommended since it is universally available and not expensive and insures uniform results.

4. Procedure for Preparing 8F Test Mixture

The following procedure was followed in preparing the 8F windshield wiper/washer test dirt mixture:

a. A 2% solution of Gelvatol 20-60 poly(vinyl alcohol) was prepared by slowly adding the required Gelvatol powder into the vortex developed by a laboratory stirrer in the required amount of deionized water. (Dowicide G - to make 4% is added to this solution when used.) The solution was stirred until the powder was dissolved.

b. 10 ml of the 2% Gelvatol 20-60 solution was added to 800 ml of deionized water.

c. 20 grams of Mineral Colloid BP and 3 grams of Ti-Pure R-900 were mixed and added to the 810 ml of Gelvatol solution. The powder mixture was slowly added into the vortex developed by the stirrer and stirring continued until the mixture was uniform with no lumps.

The dry Gelvatol could be mixed with the clay and titanium dioxide and added to the water at the same time if weighed accurately and mixed to give complete solution. The clay and Gelvatol tend to form lumps which are difficult to disperse. Slow addition of these powders into the vortex avoids this. A high shear stirrer and the use of hot water will reduce mixing time but are not necessary.

5. Substitute Materials for 8F Test Mixtures

While other materials may be found which may be substituted for the products specified, any substitution requires very careful comparison of a new formulation with that specified. Clay products from other manufacturers which are obtained from the same type of mineral deposit and have very similar chemical composition do not always perform the same. Two samples of montmorillonite clay (Volclay HPM-20 and #325, American Colloid Co.) used in test mixtures 12A and 12B with similar composition to Mineral Colloid BP gave similar dispersions to the Mineral Colloid BP except for some difference in color. When the titanium dioxide was added to the dispersions of these clays, however, flocculation occurred and the film formed was neither uniform nor continuous. Two samples of other clays of different chemical composition and origin (Veegum - reg. and Veegum T--R.T. Vanderbilt Co.) used in test mixtures 12C and 12D formed dispersions similar to those formed by Mineral Colloid BP. When the veegums were substituted for Mineral Colloid BP in the test mixture, little difference was noted and it is possible that the materials might be used without problems.

B. EVALUATION OF TEST FLUIDS

1. Test Considerations

At the outset of this program, a review was made of practices and procedures previously and currently in use for the evaluation of windshield washer performance.[1-4] Of particular interest were the SAE J942b and the FMVSS 104 procedure TP-104-04.[2,3]

The SAE J942b and the TP-104-04 procedures differ in several respects.

°In the test mixture:

SAE J942b uses a much higher percentage by volume of water than does TP-104-04.

SAE J942b includes 5% saturated salt water; TP-104-04 uses no salt.

°After application:

SAE J942b requires that the dirt film dry completely prior to performing the washer/wiper test. TP-104-04 requires that the washer/wiper test be conducted within 15 seconds after applying the dirt film.

°After operating the washer/wiper system 10 wiper cycles:

SAE J942b states that 80% of the total wash area and 90% of the wash area included in the area C shall be cleared. TP-104-04 requires that the dirt film shall be removed from not less than 60% of area A, not less than 70% of area B and not less than 74% of area C. (Areas A,B, and C are similarly defined in SAE J942b and TP-104-04.)

°SAE J942b requires both a static and dynamic test. TP-104-04 requires only a static test.

Neither the SAE J942b nor the TP-104-04 procedures specify any means to control the amount of dirt film buildup.

The SAE J942b test procedure is considered to be more demanding of the washer/wiper system than the TP-104-04 procedure. However, neither procedure is regarded to be a severe test, due primarily to the nontenacious characteristic of both of the dirt films, the relatively "thin" mixture specified by SAE J942b, and the TP-104-04 procedure which requires the washer/wiper test within 15 seconds after applying the dirt film; within this time span the dirt film would still be wet and easier to remove by the wipers than when the film is dry.

Following the review of existing windshield washer test procedures, experimental tests were performed to further evaluate and to update the test procedure. In conjunction with the development of the procedure, experimental dirt films were evaluated; these experimental dirt films were discussed in Section II-A, preceding.

Points of concern in developing a new test procedure were the following:

°Could a method be found to apply uniform dirt film to a specified density on the windshield?

°Could practical, objective methods be found to measure the uniformity and quantity of dirt film applied to the windshield?

°Does the condition of the dirt film prior to testing, e.g., does degree of dryness affect the test?

°Could objective methods be found by which to assess the effectiveness of the washer/wiper system?

°What duty cycle of the washer/wiper system is best suited for the test procedure?

2. Method of Application of Dirt Film

Various ways to apply a dirt film were evaluated. Air operated sprayers, hand sprayers, a paint roller, pouring directly from a container and pouring into a fixture or trough for uniform distribution of the fluid were tried. The preferred method is the use of a hand sprayer. To obtain uniformity of buildup of the dirt film, the best approach has been found to be the application of the film using the following procedure:

°Thoroughly clean the glazed surface with a commercial glass cleaner.

°Wipe the cleaned surface with a sponge or cloth soaked in distilled (or deionized) water.

°While the glazed surface is still wet, spray the dirt film solution on the glazed surface with a hand operated sprayer until the glass is completely wet. Continue to apply the dirt film solution starting at the top and working toward the bottom until the dirt solution is draining freely. When a uniformly wet surface has been obtained with no air bubbles or dry spots, the wetting is discontinued and the film allowed to dry.

The use of a hand sprayer in applying the test dirt film is illustrated by Figure 1. Figure 2 shows the wet dirt film immediately after being applied. By thoroughly wetting the glass and allowing the excess fluid to drain, uniformity can be achieved from one test to the next. The hand sprayer is readily available from commercial cleaning equipment sources at nominal cost.

3. Measurement of Dirt Film

No practical objective methods to measure the dirt film thickness or quantity of film applied to a windshield area were found. A predetermined weight of film could be applied to a known area; however, the problems of preventing run-off of the application would complicate the procedure. A highly viscous film that would not drip or run was considered and could be applied at a selected weight per area rate. This approach would present a problem of nonuniformity of thickness and possibly an excessive amount of dirt for the wipers to remove.

A preferred approach to determining the consistency of the quantity of film applied is to measure the opacity of the film. Opacity can be determined by taking photometric readings of a light source through a windshield before and after the dirt film has been applied. By taking the

FIGURE 1. HAND SPRAYER BEING USED TO APPLY 11B (8F) DIRT FILM. WIPER ARMS ARE BLOCKED UP OFF OF WINDSHIELD.

FIGURE 2. WET DIRT FILM 11B (8F) SHOWN IMMEDIATELY AFTER BEING APPLIED BY HAND SPRAYER (FIG. 1).

"before and after" light transmission readings, a light transmission factor can be established for the dirt film. This factor is defined as the ratio of the light reading through a windshield covered with the test mixture to the light reading through a clean windshield.

Transmission factors determined in the above described manner show good repeatability for a given dirt formulation. The film can be made more opaque by applying additional applications after the first has dried. Table 3 lists experimentally determined transmission factors for the recommended dirt film formulation 8F. From these experimentally determined transmission factors, an allowable transmission factor range of 0.20 to 0.45 is recommended for the 8F formulation. A dirt film with a transmission factor out of this range should be removed and reapplied.

4. Test Conditions

Factors investigated for their influence on washer/wiper test results were temperature, humidity and drying time. The slope of the vehicle windshield was also recorded since the slope might influence the rate at which the wet dirt film drained off.

Table 3 gives transmission factors measured for the 8F film and the ambient temperature, relative humidity, drying time and windshield slope.

A comparison of light transmission factor vs. windshield slope is given in Table 4 for dirt film formulation 8F. The data show a trend toward a higher transmission factor as the windshield slope increases. An exception is the Volvo 244D6 vehicle.

A comparison of light transmission factor vs. relative humidity can be made from Table 5. Relative humidity in the 39 to 69% range seemed not to affect the dirt film transmission factor.

Drying time prior to performing the washer/wiper test was not extensively evaluated. The limited test data, however, indicate that one hour drying time is sufficient for the ranges of temperature and humidity shown in Table 3.

5. Criteria for Acceptance

The present Laboratory Procedure TP-104-04 requires that specified percentages of areas A, B, and C be cleared of the test film within 10 wiper cycles. The specified percentages for passenger cars are:

.Not less than 60% of Area A,
.Not less than 70% of Area B,
.Not less than 74% of Area C.

For vehicles other than passenger cars, not less than 75% of a designated wiped pattern is to be cleared. The areas A, B and C are defined in References 2 and 3. It was not considered necessary in this study to change these areas or to redefine the manner in which they are located. However, based on the experience accumulated with the 8F test mixture, it is recommended that 85% of the critical area C should be cleared when tested according to the procedure

TABLE 3. LIGHT TRANSMISSION FACTORS OBTAINED FOR 8F TEST FILM. TEST VARIABLES ARE AMBIENT TEMPERATURE, RELATIVE HUMIDITY, DRYING TIME AND WINDSHIELD SLOPE.

Car	Transmission Factor	Temperature °F	Relative Humidity %	Drying Time, Hours	Windshield Slope, Degrees From Horizontal
Pacer	0.20	65	49	10	31
Pacer	0.26	65	52	2	
Pacer	0.26	67	59	3	
Volvo	0.25	60	44	1	40
Volvo	0.24	63	39	3	
Volvo	0.19	74	49	1	
Dodge	0.42	66	45	1	49
Buick	0.32	76	39	2	36.5
Buick	0.31	74	40	1	
Aspen	0.32	70	69	1	37
Aspen	0.32	73	59	1	
Aspen	0.32	69	65	1	
Aspen	0.47	70	48	1	
Aspen	0.31	70	49	1	

TABLE 4. DIRT FILM TRANSMISSION FACTOR VS. WINDSHIELD SLOPE

Vehicle	Windshield Slope, From Horizontal, Degrees	Transmission Factor (Mean)
1976 AMC Pacer	31	26 (10 hr. drying time omitted)
1977 Buick LeSabre	36.5	34.8
1976 Dodge Aspen	37	34.8
1976 Volvo 244DL	40	22.7
1976 Dodge Van	49	42

TABLE 5. DIRT FILM LIGHT TRANSMISSION FACTOR VS. RELATIVE HUMIDITY

Relative Humidity %	Dirt Film Transmission Factor
39	.24
39	.32
40	.31
44	.25
45	.42
48	.47
49	.20
49	.19
49	.31
52	.26
59	.26
59	.32
65	.32
69	.32

given in the following section. The percentages specified to be cleared in areas B and C are considered satisfactory.

The technique for calculating the percentage of cleared area is given in Reference 3. This approach involves some subjectivity in distinguishing between cleared and "almost" cleared areas. This problem is partially alleviated by the chosen test mixture in that there is usually a well defined boundary for the areas not cleared.

One method to avoid subjectivity in judging the extent of removal of the dirt film was considered. This method uses a photographic technique in which a critical area of the windshield located in front of the driver is photographed. Black and white film is used. Exposures are made of the critical area of a windshield after a dirt film has been applied, then after the film has been subjected to the specified washer/wiper cycle and finally after the windshield has been thoroughly cleaned. All factors effecting exposure and development of the film are kept constant. The resulting negatives are then analyzed for their light transmission characteristics using a light source and a suitable photometer or densitometer. Differences in light transmission factors between negatives from well cleaned and poorly cleaned windshields would be used as objective data for pass-fail criteria. A similar photographic approach has been used to determine the illumination of roadway targets during headlamp evaluations[5]. This approach to establishing an objective method of assessing the completeness of dirt film removal was examined briefly. However, available densitometers were too limited in scan area for practical use. The approach is thought to have merit for further consideration, if the procedure outlined in Section II-C, following, is found to be too subjective.

6. Washer Duty Cycle

The test procedures given in References 2 and 3 each specify that the washer capability test be conducted using 10 cycles of the wiper while applying washer fluid. Experience on this program has shown that the 10-cycle requirement presently specified is satisfactory.

7. Vehicle Testing

Numerous vehicles were used throughout the program for the evaluation of different test fluids. The vehicles ranged in age from a 1966 AMC Ambassador to a 1977 Buick LeSabre.

The intentional selection of older vehicles was done to observe performance with washer systems that have poor cleaning capabilities. The selection of the test mixture was guided to some extent by the use of washer systems that might be considered inadequate by 1976 model year standards. A guideline in choosing the test mixture was to select a film that could be easily removed by the best washer systems available, yet not be completely removed by the older, less effective washer systems.

Demonstrations of the selected test fluid were performed on 1976 models of the Dodge Aspen, the AMC Pacer and Ford and Dodge vans.

Table 2 lists the different vehicles on which the experimental formulations were tested; comments regarding the different test fluids are given. The chosen 8F fluid evolved through a process of selection whereby the constituents were chosen to give the desired tenacity and visibility to the film. Table 6 lists details of the washer/wiper systems of the test cars.

Figures 3 through 6 show washer/wiper test results on four cars using the selected 8F test fluid. For these tests, attention was directed to the driver's side of the windshield; the passenger's side was not always covered with the test film. A dark background was placed inside the vehicles for contrast when taking the photographs.

The AMC Pacer in Figure 3A and the Ford Elite in Figure 4A each had the washer nozzles mounted on the wiper arms. Two jets of washer fluid were directed to the windshield from this nozzle. This type of washer fluid distribution generally performed well on the driver's side except at the left most two or three inches of blade travel where washer fluid did not directly strike the dirt film. Figure 3B shows the dirt film 8F on the windshield of the Pacer after drying for two hours. Figures 3C and 3D show the dirt film remaining after 5 and 15 cycles respectively of the washer/wiper system. Figure 4B shows the 8F dirt film of the Ford Elite after one hour drying time. Figure 4C shows the same film after operating the washer/wiper system for 10 cycles. (One sweep by the wiper arm across and back is defined as one cycle.)

Figure 5A shows a 1976 Dodge van on which the washer nozzle is mounted on the wiper arm and the nozzle has a four-jet continuous spray at each wiper. Figures 5B and 5C show the 8F dirt film before and after operating the washer system. With this system, some dirt film remained at areas where the washer fluid jets did not directly strike the dirt film.

A 1976 Dodge Aspen shown in Figure 6 has a washer system which uses two jets on each side of the windshield. The nozzles are located at the air intake grills behind the hood. The two jets of washer fluid are vertically oriented with respect to each other.

Figures 7A and 7B show the 8F film on the Aspen windshield before and after operating the washer system.

Figures 8A and 8B show the 11B dirt film on the Aspen windshield before and after operating the washer system. The 11B test fluid is the same as 8F except that a new lot of Mineral Colloid BP was used.

Figures 9A and 9B show the 11C test film on the Aspen windshield before and after operating the washer/wiper system. The 11C test film is the same as 11B except that .4 g of Dowicide G fungicide was added to the dirt film to prevent any possibility of mold growth during long-term storage.

A comparison of tests of the 8F, 11B and 11C test films show little difference in washer/wiper performance on the driver's side, although the 11B film seemed to be more completely removed at the top of the wiped

FIGURE 3A. VIEW OF 1976 AMC PACER TEST VEHICLE WITH 6 CYLINDER 225 CID ENGINE AND AUTOMATIC TRANSMISSION. WASHER NOZZLE IS MOUNTED ON WIPER ARM AND HAS A TWO-JET CONTINUOUS SPRAY AT EACH WIPER. PHOTOMETER POSITION TO OBTAIN LIGHT READING THROUGH WINDSHIELD IS SHOWN.

FIGURE 3B. 8F TEST FILM ON LEFT SIDE OF 1976 AMC PACER WINDSHIELD.

FIGURE 3C. 8F FILM REMAINING ON AMC PACER AFTER OPERATING WASHER/WIPER SYSTEM 5 CYCLES.

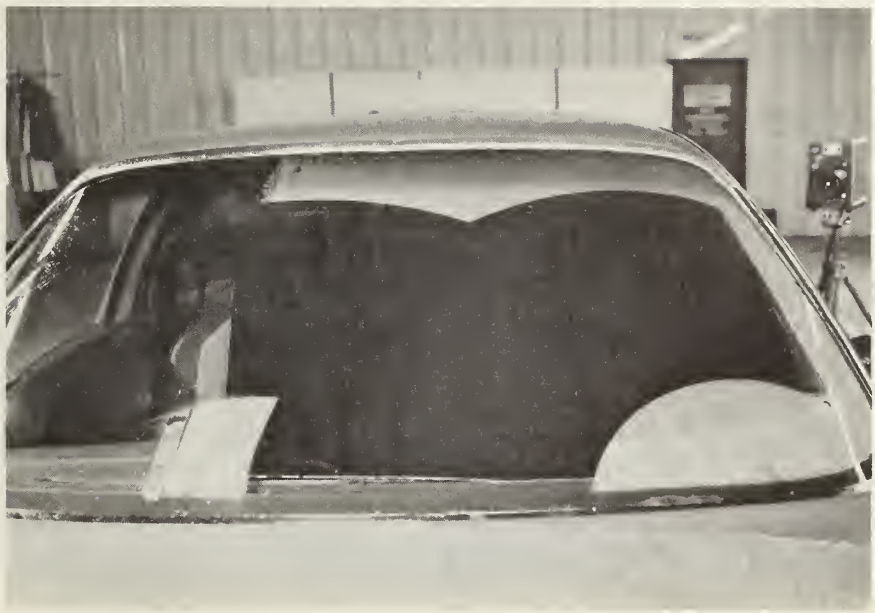

FIGURE 3D. 8F FILM REMAINING ON AMC PACER AFTER OPERATING WASHER/WIPER SYSTEM 15 CYCLES.

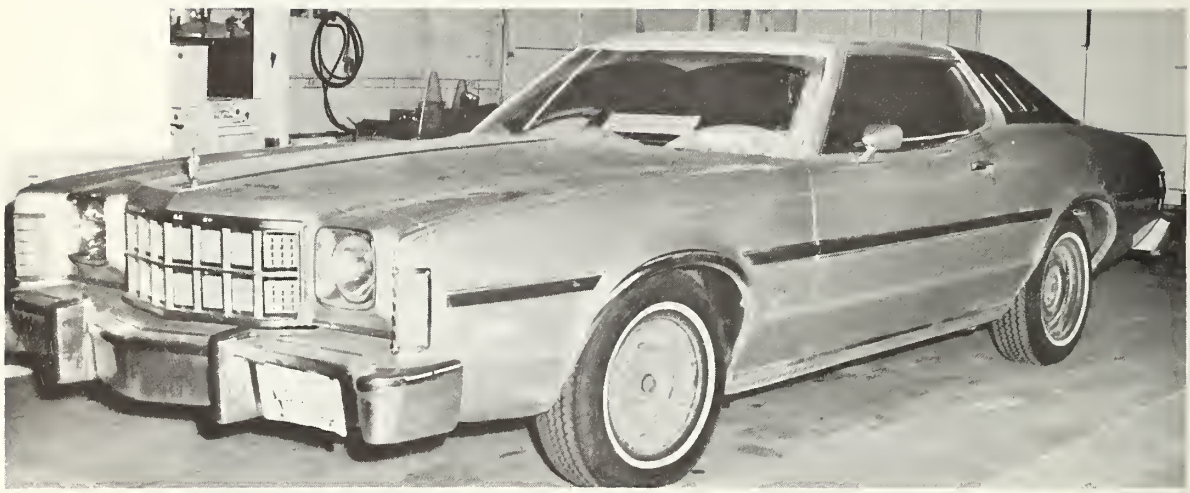

FIGURE 4A. VIEW OF 1976 FORD ELITE TEST VEHICLE, VIN NO. 6G21H115610 WITH 351 CID ENGINE AND AUTOMATIC TRANSMISSION. WASHER NOZZLE IS MOUNTED ON WIPER ARM AND HAS A TWO-JET CONTINUOUS SPRAY ON EACH SIDE.

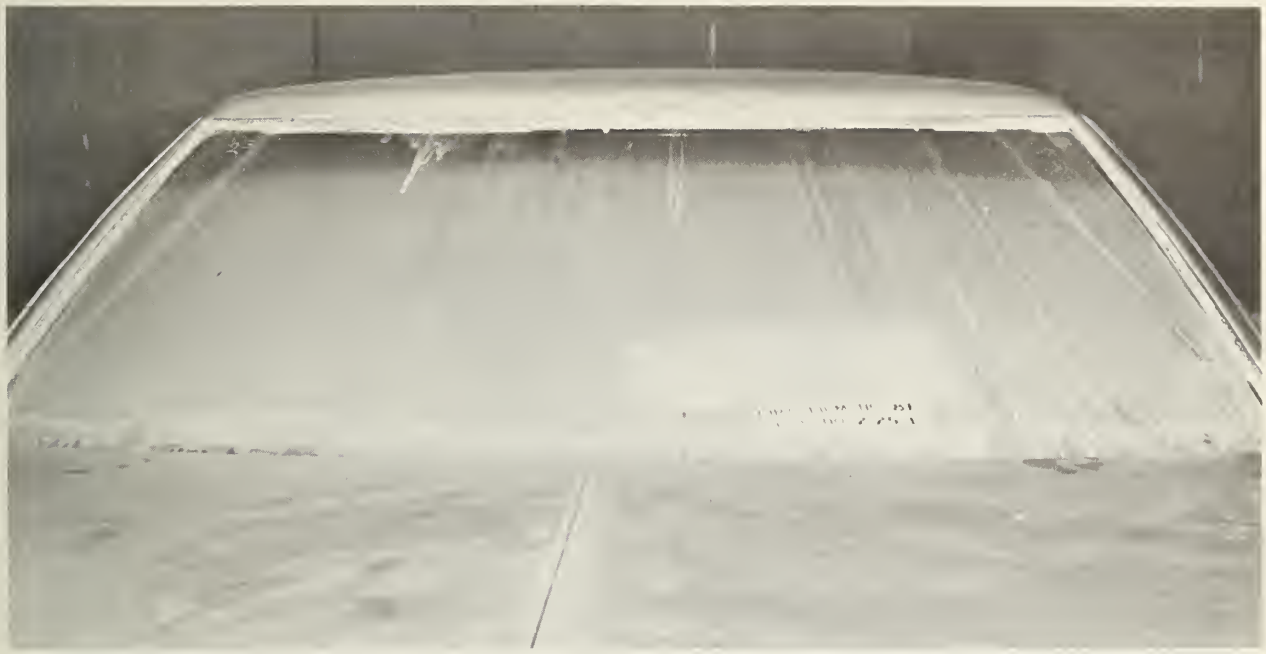

FIGURE 4B - 8F TEST FILM ON 1976 FORD ELITE WINDSHIELD AFTER DRYING FOR ONE HOUR.

FIGURE 4C. 8F FILM REMAINING ON AMC PACER AFTER OPERATING WASHER/WIPER SYSTEM 10 CYCLES.

FIGURE 5A. VIEW OF 1976 DODGE VAN TEST VEHICLE, VIN NO. B26BF6X145217 WITH 360 CID V8 ENGINE AND A727 AUTOMATIC TRANSMISSION. WASHER NOZZLE IS MOUNTED ON WIPER ARM AND HAS A FOUR-JET CONTINUOUS SPRAY AT EACH WIPER.

FIGURE 5B. 8F TEST FILM ON 1976 DODGE VAN WINDSHIELD.

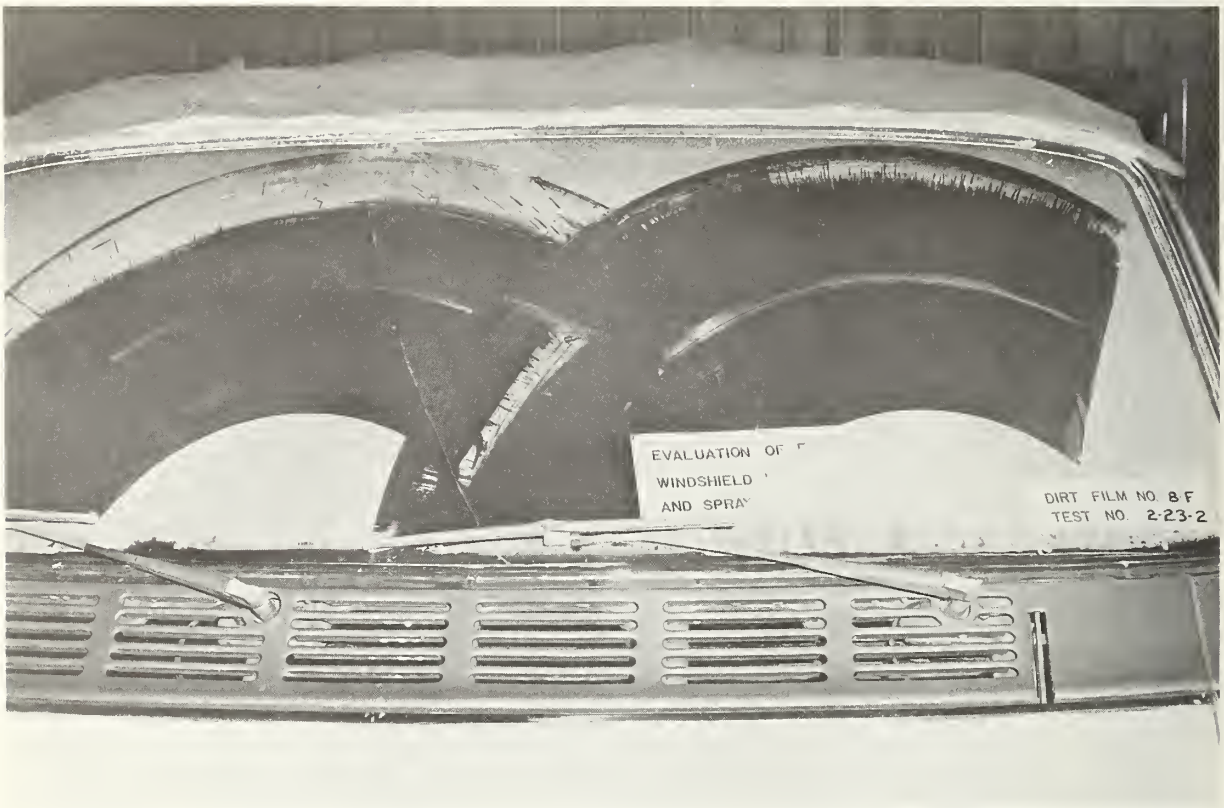

FIGURE 5C. 8F FILM REMAINING ON DODGE VAN WINDSHIELD AFTER OPERATING WASHER/WIPER SYSTEM 15 CYCLES.

FIGURE 6. VIEW OF 1976 DODGE ASPEN TEST VEHICLE, VIN NO. NL41C6F186916, WITH A 6 CYL 225 CID ENGINE AND AUTOMATIC TRANSMISSION WASHER SYSTEM USES TWO JETS ON EACH SIDE WITH CONTINUOUS SPRAY. WASHER JET STREAMS ARE PAIRED IN VERTICAL ORIENTATION.

FIGURE 7A. 8F TEST FILM ON ASPEN WINDSHIELD.

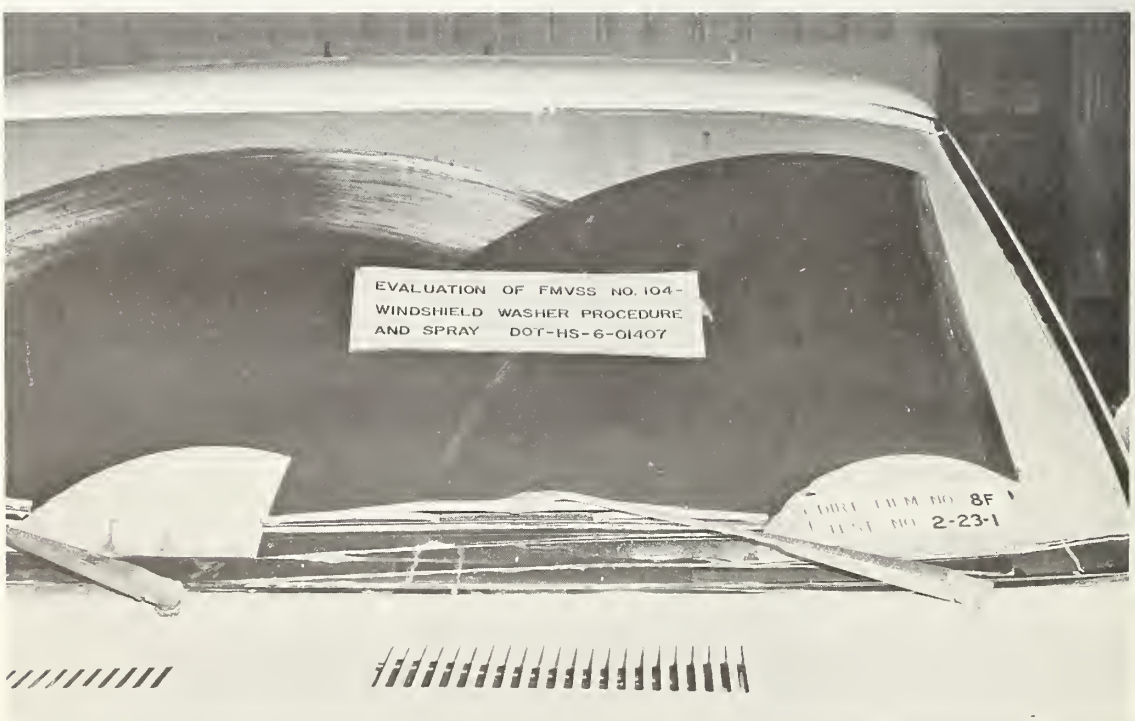

FIGURE 7B. 8F TEST FILM REMAINING ON ASPEN WINDSHIELD AFTER OPERATING WASHER/WIPER SYSTEM 10 CYCLES.

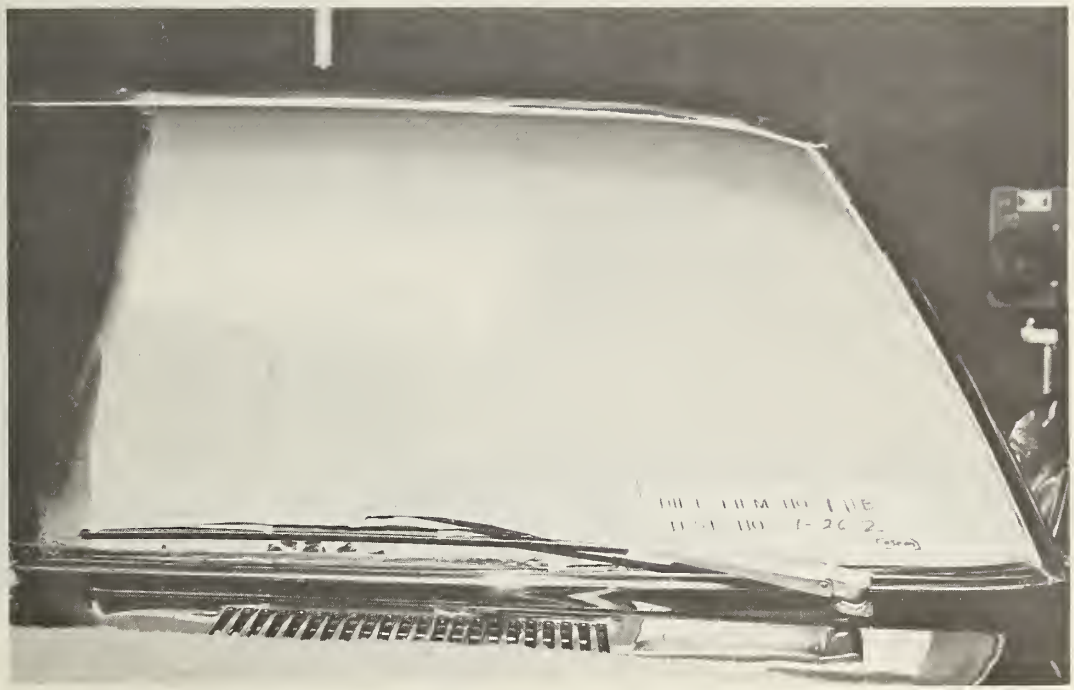

FIGURE 8A. 11B TEST FILM ON ASPEN WINDSHIELD.

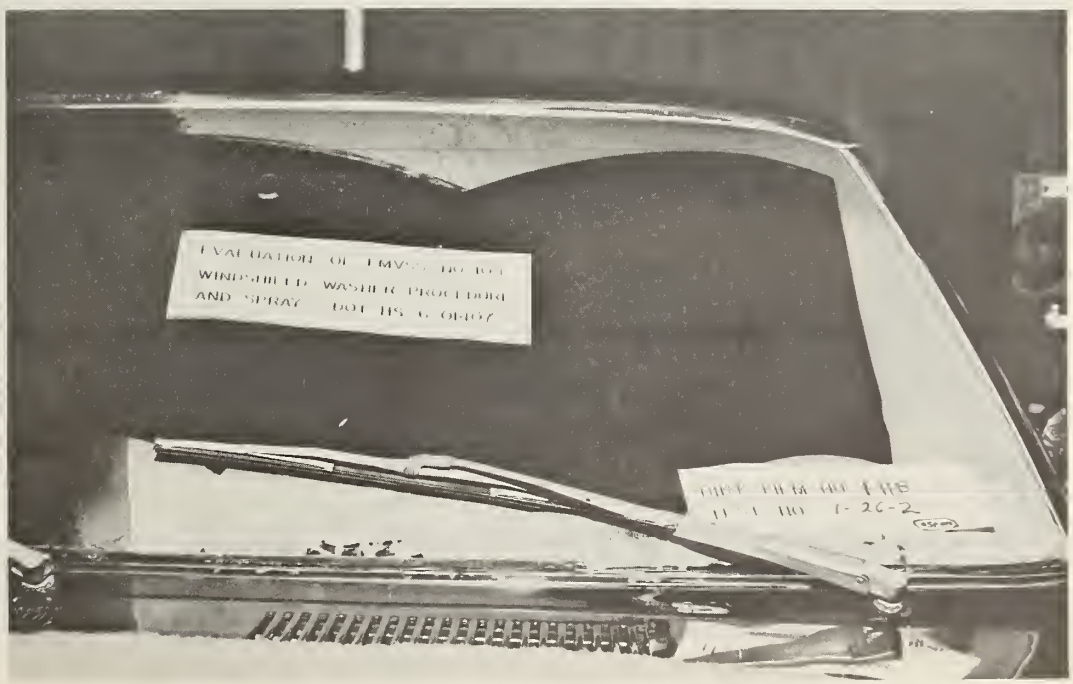

FIGURE 8B. 11B TEST FILM REMAINING ON ASPEN WINDSHIELD AFTER OPERATING WASHER/WIPER SYSTEM 10 CYCLES.

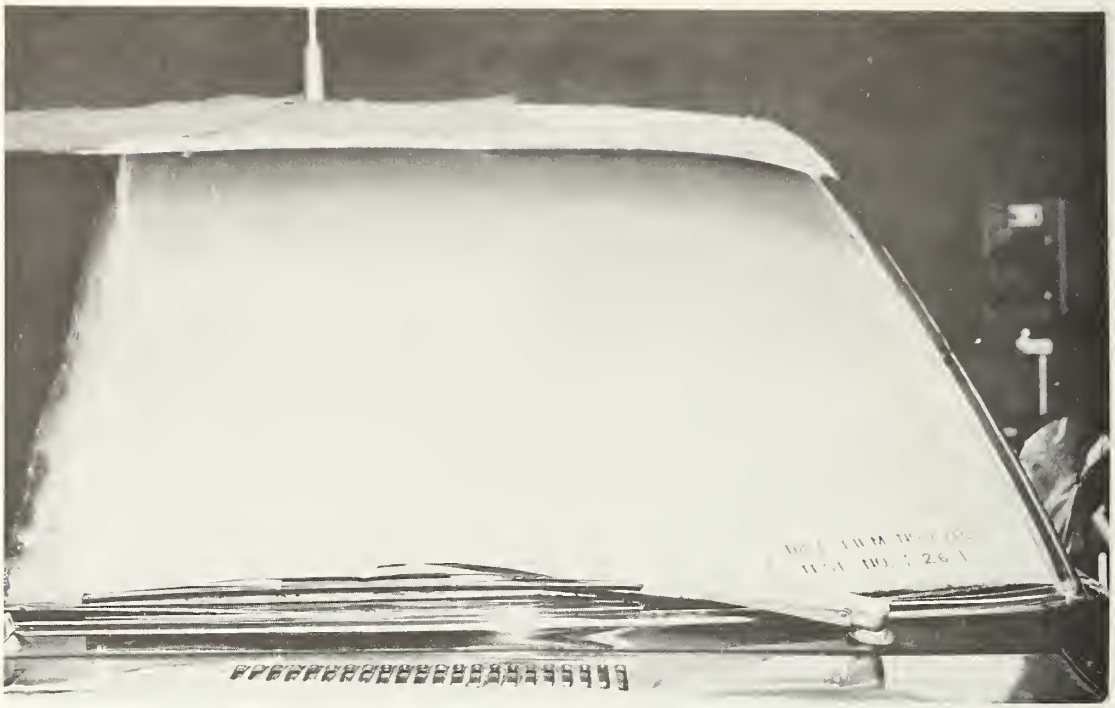

FIGURE 9A. 11C TEST FILM ON ASPEN WINDSHIELD.

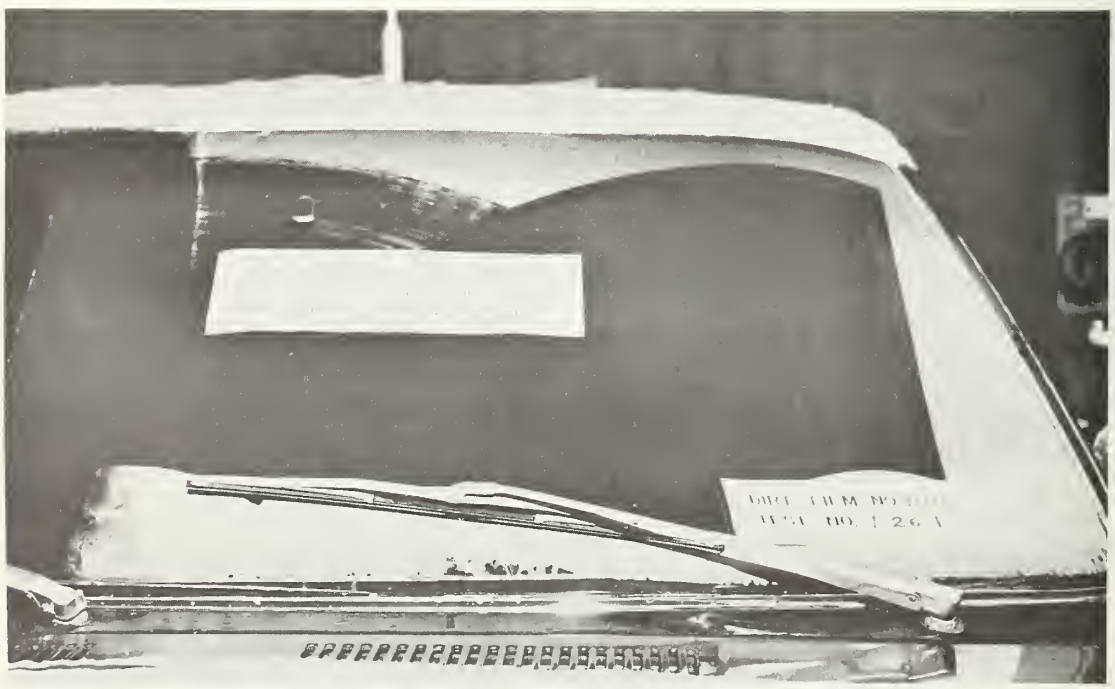

FIGURE 9B. 11C TEST FILM REMAINING ON ASPEN WINDSHIELD AFTER OPERATING WASHER/WIPER SYSTEM 10 CYCLES.

area on the passenger side. This difference is influenced by the fact that the 11B film was not applied completely across the windshield; emphasis was placed on the washer/wiper performance on the driver's side.

Performance of the 8F test fluid and of most of the other experimental formulations evaluated were recorded on 35mm slides. Slides showing test procedure and washer spray patterns were also made. A listing and a commentary on these slides were transmitted to NHTSA separately and are not included in this report. Appendix B contains a listing of these slides.

C. RECOMMENDED TEST PROCEDURE

1. General Requirements

A passenger car, multipurpose passenger vehicle, truck, or bus, equipped with a windshield wiping and washing system shall be exposed to a test dirt film applied to the exterior windshield glazing surface. The windshield washer system in conjunction with the windshield wipers shall be capable of delivering and distributing sufficient fluid to clear the test dirt film from specified windshield surfaces within 10 wiper cycles. The dirt film shall be removed from the areas outlined below. Areas A, B and C are defined in References 2 and 3.

a. Passenger Cars

(1) Not less than 60% of Area A,

(2) Not less than 70% of Area B,

(3) Not less than 85% of Area C.

b. Multipurpose Passenger Vehicles, Trucks, and Buses

Not less than 75% of the designed wiped pattern as furnished by the Department of Transportation.

2. Procedure

a. Empty the windshield washer reservoir of any washing fluid. Flush the reservoir with distilled water and refill with distilled water.

b. Actuate the windshield washer and wiper system. Verify that the systems are operating properly. Verify that the washer nozzles are properly adjusted so the fluid spray is applied to the windshield glazing surface target area as specified in the vehicle manufacturer's service manual.

c. Outline the windshield washer test areas on the interior windshield glazing surface as follows:

(1) Clean the exterior and interior surfaces of the vehicle windshield prior to testing with a commercial glass cleaning agent to provide an oil and grease free surface for marking the dimensional area as required. Make a final wash with distilled or deionized water. Wipe the glazed surface dry with a clean lintless cloth.

(2) Outline the boundaries of the test area on the inner windshield glazing surface. Refer to Reference 2 or 3 for the method to locate the test areas.

d. Record ambient temperature and relative humidity. Ambient temperature must be not less than 50°F and not more than 90°F. Relative humidity must be not less than 30% and not more than 80%.

e. Measure light transmission through windshield. Using a suitable photometer and a calibrated light source, position the photometer and the light source so that the line of sight of the photometer is through the left front door opening through a spot on the windshield directly in front of the driver and midway from top to bottom of the windshield and directed at the center of the light source. A diffused light source of 30 to 50 foot-lamberts is suggested. Once positioned, the photometer and light source are not to be moved until after the photometer reading has been taken through the dirt film applied to the windshield. Measure and record the light intensity in foot-lamberts through the clean windshield.

f. Apply the specified test dirt film to the windshield glazing surface. Thoroughly shake the test dirt film solution prior to filling the hand-type atomizer. After filling the atomizer, spray the test dirt film on the windshield glazing surface beginning at the top of the surface. Thoroughly wet the glazing surface working back and forth horizontally and proceeding downward until the entire surface is wet and draining. Allow the test dirt film to dry one hour. See page 13 for the method of application.

g. Measure light transmission through the windshield with the dry test dirt film. Move the car slightly and take a second reading and use the average of the two readings. Calculate the transmission factor or the test dirt film. This transmission factor is the ratio of the light transmission through the clear windshield. This transmission ratio is a quantitative indication of the amount of test dirt film applied. This ratio must range between 0.20 to 0.45. If the ratio is outside these range limits, the film is to be cleaned off and reapplied.

h. Photograph, using black and white film, the windshield with the test dirt film applied. The photograph is to contain printed information identifying the vehicle or test number. A black background inside the car is recommended.

i. Start the vehicle engine and operate it at idle speed while operating the windshield wiper/washer systems.

j. Actuate the windshield washer and wiper systems. If the wiper system has more than one steady speed, operate the wiper at its slowest speed. At the completion of 10 cycles, turn off the washer and operate the wipers not over two more cycles.

k. Turn off the test vehicle engine, allow the exterior windshield surface to dry for fifteen minutes and again photograph the windshield.

l. Mark on the interior surface area of the windshield the outline of the areas that have not been cleared of the test dirt film.

Using heavy clear vellum, make a pattern of the entire windshield glazing area. Place the vellum on the exterior windshield glazing surface and with a grease pencil, trace onto the vellum the windshield outline. Remove the vellum and cut out the outline pattern. Replace the finished pattern on the exterior windshield surface. Trace onto the vellum pattern the outline of the test areas and the outline of the areas of the windshield not cleared by the windshield washer system with a grease pencil. Measure and record the percentage of the test areas that were cleared on a data sheet. Lines forming a grid of 1/2 inch squares can be drawn on the vellum pattern to assist in determining the percentage of test area not cleaned.

m. Using a nonabrasive cleaner, thoroughly reclean the exterior of the windshield glazing surface. Again using a nonabrasive cleaner, remove from the interior windshield glazing surface the outlines of the cleared areas taking care not to remove the outlines of the test areas.

n. Repeat the test procedures outlined beginning with step d for a total of two capability test cycles.

o. At the conclusion of the second test, calculate the corresponding percentages of cleared areas for each of the two vellum patterns and provide an average cleared area for the two tests.

III. DISCUSSION

A. TEST MIXTURE

Test mixtures formulated to duplicate road films encountered by vehicles in use have appeal in that such mixtures provide a test condition similar to actual highway conditions. However for a compliance test for which conditions must be repeatable at any manufacturer's facility or at any test laboratory, a test mixture of actual road film presents various problems, the first of which is the selection of the test dirt. The composition of an actual road film will vary widely depending upon geographic location as well as urban or rural useage. Seasons, too, will cause the composition of the dirt film on a windshield to vary. Thus it is thought that no single dirt film exists that can represent all road conditions at all times.

SwRI tested one film, 4B, developed on a prior contract for NHTSA which was formulated to represent an actual road film.[1] The following comments are made regarding this test mixture:

1. Components of the mixture are not easily and precisely defineable and thus would not be exactly duplicated by all testing facilities.

2. Components of the mixture do not remain in suspension for sufficient time to assure a uniform application of the film.

3. Storage life of the mixture is unknown.

4. The test film is too easily removed by the washer/wiper system to be meaningful for compliance testing.

The first three of the above comments are thought to be applicable to any formulation designed to use ingredients actually found on windshields during highway driving.

In light of the above discussion, it was considered appropriate to depart from the use of a test mixture that contains ingredients actually found on windshields. Instead, an effort was made to develop a dirt film using components that are easily duplicated, simple to mix and apply, and that would permit an objective evaluation of windshield washer systems.

The 8F formulation developed in this study is thought to be a dirt film that will meet the requirements essential for compliance testing. This 8F formulation exhibits the following properties:

1. The components are well defined and sources are available.

2. Component costs are low.

3. Shelf life of prepared mixtures is good. Shelf life of the mixture without the addition of a fungicide is estimated to be in excess of six months. The shelf life can be extended indefinitely by the addition

of a small amount of fungicide. However the low cost of the components and the ease of preparation eliminate any substantial advantages of long-term storage.

4. The test mixture components remain in suspension quite well.

5. The mixture is easily and uniformly applied with an inexpensive hand sprayer.

6. The degree of difficulty of removal is sufficient to identify washer systems that perform poorly. Conversely good washer systems currently in production will remove the test film adequately.

7. Remaining test dirt film, after operating the washer/wiper system is readily visible, i.e., uncleaned areas can be easily identified.

B. TEST PROCEDURE

The SwRI recommended test procedure is similar in several respects to procedures specified in FMVSS No. 104, TP-104-04. One noteworthy difference is the use of photometry to establish an objective means to determine if sufficient dirt film has been applied.

The photometric approach to assessing the amount of test mixture applied does not give a film thickness nor a weight of mixture per unit area. What the approach does do is to provide an empirical control to determine if an applied film falls within preset limits of opacity. The test mixture when properly prepared and applied will reduce the light transmission through the windshield. Experimental data have been used to determine a range of light transmission ratios that is acceptable for the 8F test mixture. A light transmission ratio outside of the specified range would presumably indicate the test mixture was improperly prepared and/or applied or that some other condition prevailed which prevented the achievement of the desired amount of test mixture on the glazed surface.

In summary, the photometric measurement serves merely as a check on the preparation and application of the mixture. If good laboratory and test procedures are applied, the photometric assessment could be eliminated.

The SwRI test procedure sets limits on ambient temperatures and relative humidity. Experimental data to support these limits are limited. These limits are considered to be broad enough to avoid unnecessary delays or costs in testing. However, further studies of these limits are recommended to determine if they may, in fact, be too broad.

The pass-fail criteria used in the SwRI test procedure are similar to those used in Reference 1. Some subjectivity occurs in determining the percent of area cleared by the washer/wiper system. The presence of streaks or a very thin dirt film requires the operator to use judgement in deciding the amount of area that is to be counted as clean. Photographic techniques and the use of densitometers to measure opaqueness of film offer a possible method to objectively rate the effectiveness of washer/wiper systems. If a strongly objective method of compliance testing is required, a study of this photographic/densitometer approach is suggested.

TABLE 6. WINDSHIELD WIPER/WASHER DESIGN DETAILS OF CARS USED TO EVALUATE TEST MIXTURES

Vehicle	Blade Length, In.	Arm Force Against Blade, Oz.	Wiper Speed,* Cycles/Min.	Slope of Windshield From Horizontal, Degrees	Tint (T) Nontint (N) Glass	Light Transmission Ratio Through Clean Windshield	Washer Nozzle Location And Type**	Continuo... Or Pulsi...
'66 AMC Ambassador	15	17	92	42	N	.86	Hood 2 V	I
'76 AMC Pacer	18	24	55/40	31	T	.65	Wiper Arm 2AV	C
'77 Buick LeSabre	18	27	60/33	36.5	T	.66	Under Hood 2 V	I
'76 Chevette	16	20	55/30	37	N	Not Obtained	Hood 2 H	
'66 Chevrolet Impala	15	17	52/27	35	N	.76	Hood S	I
'73 Chevrolet Impala	18	27	55/33	32	T	.60	Under Hood 2 H	P
'76 Dodge Aspen	18	25	75/34	37	T	.66	Hood 2 V	C
'76 Dodge Van	16	25	Not Obtained	49	N	.73	Wiper Arm 4 V	C
'76 Ford Elite	16	23	60/38	32	T	.60	Wiper Arm 2AV	C
'76 Oldsmobile Cutlass	16	24	67/46	35	T	.65	Under Hood 2 H	I
'76 Plymouth Gran Fury	18	26	43/29	34	T	.64	Wiper Arm 4 V	C
'76 Volvo 244DL	16	17	30/55	40	T	.78	Hood S	

*Wiper speeds measured with windshield wet.

**Code for Nozzle Type
S -Single jet each side of windshield.
2V -2 Jets each side oriented in vertical plane.
2H -2 Jets each side oriented horizontally to each other.
2AV-2 Jets each wiper arm oriented in vertical plane.
4V -4 Jets each wiper arm oriented in vertical plane.

IV. RECOMMENDATIONS

Based on the findings of this study, the following recommendations are offered:

1. The test mixture designated 8F and described in Section II-A-2 and 3 is recommended for further evaluation. This evaluation should be made by organizations presently performing or are familiar with compliance testing to Procedure TP-104-04 or by organizations such as the SAE technical committee on windshield wipers. Ideally, this evaluation should include the procurement and preparation of the test film components and an evaluation of the test mixture on vehicles. This trial run would serve to confirm the usefulness of the proposed film and/or to identify any problem areas needing further refinement.

2. Further studies of the effects of temperature and humidity should be made to provide a stronger data base in support of the specified ranges of temperature and humidity. These studies could have as a secondary objective the determination of the need or the lack of need for test dirt film application control through photometric methods assuming all other test procedures are carefully followed.

3. A method of objectively assessing the amount of test film remaining in critical areas after operating the washer/wiper system seems desirable. One method, described briefly in this report, would utilize photographic negatives obtained from film exposed to show the remaining dirt film on a windshield after testing. This film would be scanned with a densitometer or other instrument capable of measuring light transmission through the film. Empirical values for light transmission could be established for pass-fail limits. The presently recommended 8F test mixture formulation would be well suited for photographic techniques since it gives good contrast when photographed against a black background. It is recommended that a brief feasibility study be conducted to evaluate the the above photographic approach to pass-fail criteria.

APPENDIX A - SOURCES AND SPECIFICATIONS FOR COMPONENTS OF 8F TEST MIXTURE

1. MINERAL COLLOID BP*

Source: Georgia Kaolin Co.
433 North Broad St.
Elizabeth, New Jersey 07207

DESCRIPTION:

MINERAL COLLOID BP is a pure montmorillonite, an inorganic colloid. It possesses many unusual properties, such as exceptional film and gel formation. Its high exchange capacity allows complexing reactions with both inorganic and organic cations, and its unique structure enables sorption of water and a wide spectrum of organic compounds.

PHYSICAL PROPERTIES:

Color	Light amber
Form	Fine, thin flakes or microgranules
Solubility and Dispersibility	Insoluble in water and organic solvents. Disperses easily in water to form colloidal suspension. Can be treated to disperse in organic liquids.
Moisture, %	5 - 8
pH (5% solids in distilled water)	9.0 $\pm$ 0.5
Swelling, ml. (2 g./100 ml. H_2O)	Approximately 40

CHEMICAL FORMULA:

$$(Si_{7.34}Al_{0.66})(Al_{3.18}Fe^{3+}_{0.37}Mg_{0.54})\ O_{20}\ (OH)_4(Ca_{0.10}K_{0.04}Na_{0.68})$$

THE INFORMATION CONTAINED HEREIN IS BASED ON TESTS BELIEVED TO BE RELIABLE HOWEVER NO WARRANTY IS IMPLIED

*Data obtained from manufacturer's literature.

TYPICAL CHEMICAL ANALYSIS:

% SiO_2	55.66
Al_2O_3	24.40
MgO	2.72
Fe_2O_3	3.68
K_2O	0.21
Na_2O	2.62
CaO	0.72
TiO_2	0.20
Loss on Ignition (1000° C.)	9.71
Cation Exchange Capacity, meq./100 g.	90

GENERAL PROPERTIES:

Dispersion — MINERAL COLLOID BP disperses readily in water to form a colloidal suspension. For best results, MINERAL COLLOID BP should be added slowly to the water with agitation, preferably using a high speed mixer. The use of hot water (150° F.) greatly facilitates dispersion, but is not a requisite.

Viscosity — MINERAL COLLOID BP dispersed in water is unique in that it does not produce the usual gel associated with montmorillonite in low concentration. Suspensions up to 5% concentration of MINERAL COLLOID BP are smooth, pourable fluids, not gels. Above 5% concentration the viscosity increases rapidly and at approximately 10% concentration the consistency approaches a smooth, viscous gel.

Typical viscosities of MINERAL COLLOID BP dispersed in water are listed below.

% MINERAL COLLOID BP	Brookfield Helipath Viscosity (CPS) 5 RPM
4	25
5	120
6	400
7	5,000
8	18,500
9	76,000

Reactivity

MINERAL COLLOID BP, owing to its high ion exchange capacity, can interact with both inorganic or organic cations. The predominance of sodium as opposed to calcium in the exchange positions greatly facilitates the interaction.

In water, the exchange cations can be replaced by calcium, magnesium, barium, hydrogen and other cations.

Amine salts are typical organic compounds which can interact. MINERAL COLLOID BP also can sorb many polar organic liquids, including many alcohols, polyols, and amines.

SUGGESTED APPLICATIONS:

Inorganic film former and binder	MINERAL COLLOID BP will form films which are non-flammable, stable at elevated temperatures, and resistant to microbial degradation.
Stabilizing emulsions and suspensions	MINERAL COLLOID BP is useful as a stabilizing agent for emulsions, emulsion polymerization, and suspended solids.
Bodying and thickening agent	The closely controlled viscosity character of MINERAL COLLOID BP makes it a reliable additive for bodying and thickening many systems.

THE INFORMATION CONTAINED HEREIN IS BASED ON TESTS BELIEVED TO BE RELIABLE. HOWEVER, NO WARRANTY IS IMPLIED

2. GELVATOL 20-60 POLY(VINYL) ALCOHOL**

SOURCE: Monsanto (see A-6 for district offices)

PROPERTIES

TABLE 1

Characteristics(1) of Gelvatol(R) Resins

Resin Grade	Viscosity(2) (centipoises)	% Residual(3) polyvinyl acetate	% Hydrolyzed	Molecular weight (approx. wt. avg.	% Ash (max.)
20-90	35-45	20-25	88.7-85.5	125,000	0.75
20-90BP*					
20-60	21-25	20-25	88.7-85.5	96,000	0.75
20-60BP*					
1-30	4-6	0-3	100.0-98.5	14,000	1
20-30	4-6	20-25	88.7-85.5	10,000	0.75
20-30BP*					
40-20	2.4-3	37-42	77.0-72.9	3,000	1
40-10	1.8-2.4	37-42	77.0-72.9	2,000	1

(1) Maximum volatiles are 5% (3% as packed), ph range of a 4% solution for all grades is 5-7.

(2) Viscosity in centipoises of a 4% aqueous solution at 20°C.

(3) Determined on a weight basis.

*Same as 20-90, 20-60 and 20-30 except particle size.

**Data obtained from manufacturer's literature.

2. GELVATOL 20-60 POLY(VINYL) ALCOHOL (Cont'd.)

TABLE 2

Properties of Gelvatol(R) Resins

Property	Data	Remarks
Form	Granular powder	
Color	White to light straw	
Specific gravity	1.19-1.27	
Bulk density	30-40 lbs.ft.^{3}	
Tensile strength	Up to 14,000 lbs./in.^{2}	At 50% relative humidity
Elongation Unplasticized film Plasticized film	 Up to 300% Up to 600%	 At 50% relative humidity
Thermal coefficient of linear expansion 0-50°C plasticized	1x10-^{4}°C	An average value-depends upon grade and plasticizer content
Hardness, I.C.I. Automatic Sward Hardness Rocker	27-57%	Compared to glass, at 50% relative humidity
Abrasion resistance, unplasticized	Good to excellent	Proportional to molecular weight
Heat sealing temperature	110-150°C (230-302°F)	Unplasticized, 50% relative humidity
Heat stability	Slow degradation over 100°C (212°F). Rapid degradation over 200°C (392)F)	The resin becomes progressively more water resistant as temperature is increased
Compression-molding temperature	120-150°C (248-302°F)	Plasticized
Effect of light	Negligible	
Effect of strong acids	Dissolves and/or decomposes	
Effect of weak acids	Softens or dissolves	
Effect of alkalies	Softens or dissolves	
Effect of organic solvents	Highly resistant to most organic solvents	
Burning rate	Slow	
Mold resistance	Good	
Gas impermeability	Very high with most gases	

3. TI-PURE(R) R900 TITANIUM DIOXIDE*

SOURCE: DuPont (see following two pages for Sales Offices and Information Centers)

Property Data

Analysis:

TiO_2	94.0% Minimum
Al_2O_3	3.5% Maximum

Physical Properties

Specific Gravity	4.12
Gallons per pound	0.0292
pH	6.7 - 8.0
Volatile @105°C.	0.5% Maximum

Product Description

A general purpose rutile pigment especially suited for enamels and outside house paint. Also has excellent dispersion in plastics.

	Paint	R-900	Plastics
Average Oil Absorption	16	Relative t.s.	135-140
Relative Glass	Excellent	Lightfastness	Excellent
Relative Hiding			
Low PVC	145	Visual Whiteness	Good-Excellent
High PVC	135	Ease at Dispersion	Excellent
Relative Chalk Resistance	Excellent	Undertone	Neutral

Meets Specifications: ASTM D-476 Type II Class II
Fed. TT-P-442 Type III Grade B

Representative material will be submitted as a standard upon request.

*Data obtained from manufacturer's literature.

TI-PURE PIGMENTS DEPARTMENT

General Office:	
Nemours Bldg., Wilmington, De. 19898	(302) 774-2421
Export Office:	
Nemours Bldg., Wilmington, De. 19898	(302) 774-2421
Sales Offices:	
Atlanta, Ga. 30329 1571 Northeast Expressway, N.E.	(404) 633-0377
Chicago, Il. 60696 20 North Wacker Drive	(312) 222-4944
Cincinnati, Oh. 45206 2200 Victory Parkway	(513) 221-1415
Cleveland (Beachwood), Oh. 44122 23200 Northwestern Highway	(216) 464-9520
Detroit (Southfield) Mi 48075 26300 Northwestern Highway	(313) 353-6600 (313) 444-4200
Houston, Tx. 77027 P.O. Box 22066 2001 Kirby Drive	(713) 521-9201
New England (Wakefield), Ma. 01880 301 North Avenue	(617) 245-4855
New York (Clifton, N.J.) 07015 1170 Clifton Avenue	(201) 778-4250 (212) 971-4971
Pasadena, Ca. 91107 3750 East Foothill Boulevard	(213) 684-0925
Philadelphia, Pa. 19103 117 South 17th Street	(215) 568-6644
Minneapolis, Mn. 55435 P.O. Box 35326	(612) 944-2600
San Francisco (San Mateo) Ca. 94402 520 South El Camino Real	(415) 347-9561

PRODUCT INFORMATION CENTERS

Baltimore, Maryland (Handled by Wilmington Center)	(301) Plaza 2-2506
Chicago, Illinois 60603 7 South Dearborn Street	(312) 222-5050
Houston, Texas 77055 8125 Kempwood Drive, P.O. Box 55404	(713) 467-4449
Los Angeles, California 91505 3300 W. Pacific Avenue, Burbank, California	(213) 843-1038
New York, New York 10001 350 Fifth Avenue	(212) 971-4771
Philadelphia, Pennsylvania (Handled by Wilmington Center)	(215) Walnut 3-2193
San Francisco, California 94005 385 Valley Drive, Brisbane, California	(415) 467-9166
Washington, D.C. (Handled by Wilmington Center)	(202) Dupont 7-0416
Wilmington, Delaware 19898 Ground Floor, DuPont Building	(302) 774-2421
DuPont Personnel (Outside Wilmington area) call:	Extension 2421

SOURCES:

AREA HEADQUARTERS

Dow Chemical U.S.A.	Midland, Michigan
Dow Chemical Latin America	Coral Gables, Florida
Dow Chemical Europe S.A.	Zurich, Switzerland
Dow Chemical Pacific	Hong Kong, B.C.C.
Dow Chemical of Canada Limited	Sarnia, Ontario

DOW CHEMICAL U.S.A. SALES OFFICES

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Baton Rouge, La. 70816 11100 Mead Rd., Suite 303	293-2222
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Williamsville, N.Y. 14221 Suite 343, 5500 Main St.	631-5540
Charlotte, N.C. 28210 2 Woodlawn Green, Woodlawn Road	525-9030
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Dallas, Tx. 75251 12700 Park Central Place, Suite 600	387-2211
Southfield, Mi. 48076 Travelers Tower, Suite 415 26555 Evergreen Road	358-1300
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Houston, Tx. 77001 P.O. Box 3387	626-3170
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Shawnee Mission, Ks. 66205 Suite 203A, 4210 Johnson Drive	362-2100
Pasadena, Ca. 91109 P.O. Bin 48	577-1515
Memphis, Tn 38137 1220 Clark Tower, 5100 Poplar Ave.	767-5000
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Richmond, Va. 23288 1603 Santa Rosa Road	288-1601
St. Louis, Mo. 63105 800 Pierre Laclede Center 7733 Forsyth Blvd.	726-5000
Walnut Creek, Ca. 94596 2800 Mitchell Drive	933-3100
Bellevue, Wa. 98004 777 106th St. N.E.	455-7250
Stamford, Ct. 06902 Washington Plaza 1351 Washington Blvd.	359-3300

APPENDIX B

SLIDES OF WINDSHIELD WASHER TESTS

The slides numbered 1 through 58 show views of most of the test mixtures evaluated during the program. In most instances, a black background was placed inside the car to provide contrast. Slides 26 through 42 show views of the recommended 8F test mixture as tested on various vehicles.

Slide 59 shows the recommended method to apply the test mixture.

Slide 60 shows the photometer setup to view a light source through the windshield.

Slides 61 through 64 show washer fluid application methods of different cars.

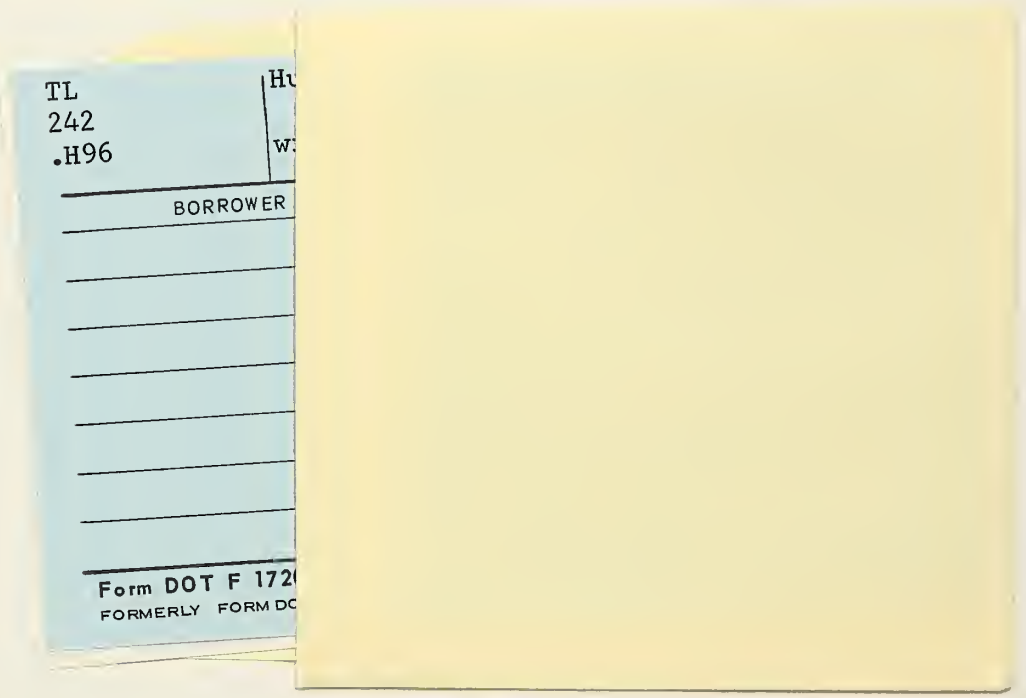
Slide 65 shows a particle suspension comparison of 4B and 8F test mixtures.

SLIDE NO.	COMMENTS
1	Test mixture 3A on 1976 Ford Elite windshield.
2	Test mixture 3A on Ford Elite windshield after 10 cycles of washer/wiper system. Mixture easily removed and remaining film difficult to see. (Building reflection is shown on black background.)
3	Test mixture 3B on 1976 Ford Elite windshield.
4	Test mixture 3B on Ford Elite windshield after 10 cycles of washer/wiper system. Film too easily removed.
5	Test mixture 3D on 1976 Ford Elite windshield.
6	Test mixture 3D on Ford Elite windshield after 10 cycles of washer/wiper system. Film too easily removed. (Building reflection is shown on black background.)
7	Test mixture 4B on 1976 Ford Elite windshield.
8	Test mixture 4B on Ford Elite windshield after 10 cycles of washer/wiper system. Film too easily removed.
9	Test mixture 4B on 1976 Dodge van windshield.
10	Test mixture 4B on Dodge van windshield after 5 cycles of washer/wiper system. Film too easily removed.
11	Test mixture 4D on 1976 Ford Elite windshield.
12	Test mixture 4D on Ford Elite windshield after 10 cycles of washer/wiper system. During washer/wiper test the dirt film formed jelly-like deposits on wiper blade which carried back and forth. Clean area was difficult to define.

SLIDE NO.	COMMENTS
13	Test mixture 4E on 1976 Ford Elite windshield.
14	Test mixture 4E on Ford Elite windshield after 10 cycles of washer/wiper system. Remaining film not easily seen.
15	Test mixture 5A on 1976 Ford Elite windshield.
16	Test mixture 5A on Ford Elite windshield after 10 cycles of washer/wiper system. Test mixture judged too hard to remove and remaining film not easily seen.
17	Test mixture 6A on 1976 Ford Elite windshield.
18	Test mixture 6A on Ford Elite windshield after 10 cycles of washer/wiper system. Test mixture was hard when dry. Mixture formed jelly-like solution when softened with water. Remaining film not easily seen.
19	Same comments as slide 18.
20	Test mixture 7C applied to 1976 Plymouth Gran Fury windshield.
21	Test mixture 7C on Gran Fury after 5 cycles of washer/wiper (Compare with slide 24).
22	Test mixture 7C on Gran Fury after 10 cycles of washer/wiper (Compare with slide 25). The 7C test mixture was hard to remove. A comparison between the Gran Fury and Aspen (slides 23-25) washer/wipers showed the Aspen system to be the best in cleaning the 7C test film.
23	Test mixture 7C on 1976 Dodge Aspen windshield.
24	Test mixture 7C on Aspen windshield after 5 cycles of washer/wiper. (Compare with slide 21.)
25	Test mixture 7C on Aspen windshield after 10 cycles of washer/wiper. (Compare with slide 22.) The continuous two-jet washer fluid distribution of the Aspen more quickly removed the dirt film than the four-jet distribution of the Gran Fury.
26	Test mixture 8F on 1976 Dodge van windshield.
27	Test mixture 8F on Dodge van after 5 cycles of washer/wiper.
28	Test mixture 8F on Dodge van after 15 cycles of washer/wiper.
29	Test mixture 8F on 1976 Ford van windshield.
30	Test mixture 8F on Ford van after 10 cycles of washer/wiper. Ford van has same washer configuration as Ford Elite (Slide 64).
31	Test mixture 8F on 1976 AMC Pacer windshield.
32	Test mixture 8F on Pacer windshield after 10 cycles of washer/wiper. Pacer has washer fluid application method similar to Ford Elite (Slide 64).

SLIDE NO.	COMMENTS
33	Test mixture 8F on 1976 Plymouth Gran Fury windshield.
34	Test mixture 8F on Gran Fury windshield after 10 washer/wiper cycles. (Gran Fury washer fluid application is shown in slide 62.)
35	View from inside Gran Fury looking through test mixture 8F after 10 cycles of washer/wiper.
36	Test mixture 8F on 1976 Dodge Aspen windshield.
37	Test mixture 8F on Aspen windshield after 10 cycles of washer/wiper. Aspen washer fluid application is shown in slide 63. (Overhead power lines are reflected from dark interior background.)
38	View from inside Aspen looking through test mixture 8F after 10 cycles of washer/wiper.
39	Test mixture 8F on 1976 Oldsmobile Cutlass windshield.
40	Test mixture 8F on Cutlass windshield after 15 cycles of washer/wiper system. Cutlass has two side-by-side jets on each side of the windshield. The nozzles are located under the hood in the wiper arm storage space. The washer fluid is applied in a pulsing flow.
41	Test mixture 8F on 1976 Volvo 244DL windshield.
42	Test mixture 8F on Volvo windshield after 10 cycles of washer/wiper system.
43	Test mixture 9D on 1976 Dodge Aspen windshield.
44	Test mixture 9D on Aspen windshield after 10 cycles of washer/wiper. Test film 9D is difficult to remove.
45	View from inside Aspen looking through test mixture 9D after 10 cycles of washer/wiper.
46	Test mixture 9E on 1976 Oldsmobile Cutlass windshield.
47	Test mixture 9E on Cutlass windshield after 11 cycles of washer/wiper. Test film 9E is difficult to remove. The areas where the two jets of washer fluid strike the glass can be seen.
48	Test mixture 9F with fluorescent pigment on 1976 Oldsmobile Cutlass. This application of the test mixture shows heavy streaks or runs which should be avoided when applying the test mixture.
49	Test mixture 9F on Cutlass windshield after 22 washer/wiper cycles. Note that the streaks or runs did not completely clean off.
50	Test mixture 9F on Cutlass windshield, after 22 washer/wiper cycles, viewed under ultraviolet light. (Compare with slide 49.)

SLIDE NO.	COMMENTS
51	Test mixture 10A (fluorescent) on Aspen windshield after 10 cycles of washer/wiper. Viewed under ultraviolet light. This 10A test mixture is too difficult to remove.
52	Test mixture 10B on 1976 Dodge Aspen windshield.
53	Test mixture 10B on Aspen windshield after 10 cycles of washer/wiper. This test film is too easily removed.
54	Test mixture 10B on 1976 Plymouth Gran Fury windshield.
55	Test mixture 10B on Gran Fury windshield after 10 cycles of washer/wiper. (Compare with Dodge Aspen slides 52 and 53.)
56	View from inside Gran Fury looking through test film 10B after 10 cycles of washer/wiper.
57	Test mixture 11B on 1976 Dodge van windshield. Test mixture 11B is identical to 8F except a new lot of Mineral Colloid BP was used. (Compare with slide 26.)
58	Test mixture 11B on Dodge van after 10 cycles of washer/wiper. (Compare with slide 28.)
59	View showing 8F test mixture being applied with hand sprayer. Windshield is wet thoroughly starting at top and working to the bottom.
60	View of photometer setup to obtain light transmission readings through windshield before and after applying test mixture. Photometry is used to assess the amount of test mixture applied; it is not used to measure remaining dirt film after operating the washer/wiper system.
61	View showing Dodge van washer fluid flowing in four jets from nozzle on wiper arm. Arm as shown is manually held off of windshield.
62	Plymouth Gran Fury water distribution on windshield Gran Fury has same arm mounted nozzle design as Dodge van (slide 61). Water paths where the four jets strike the glass can be seen.
63	View showing Dodge Aspen washer fluid jets in vertical orientation to each other. This system was considered to have the best cleaning capability of those used in the program.
64	View showing Ford Elite washer fluid flowing in two jets from nozzle on wiper arm. Wiper is shown in its left-to-right return motion.
65	View of 8F and 4B test mixtures in quart jars undisturbed after setting overnight. The poor suspension properties of the 4B mixture and the relatively good suspension properties of the 8F mixture are shown.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